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Dragless Flight Control System for Flying Objects

DEDICATORY CLAUSE

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BACKGROUND OF THE INVENTION

15 At present, no flying objects, such as missiles, utilize dual recessed fins (referred to as "canards" in cases of missiles) to control their flight.

In cases of missiles, for example, historically the flight control has been achieved by using the current standard rotational canard control. The current canard control typically involves multiple rigidly extended canards that are
20 axially rotated about the canard axis, the canard axis being normal to the main longitudinal missile axis. Such standard rotational canard control generates large control forces because of the "lift" generated by angling the canards to a desired angle into the air flowing around the missile body during missile flight. But major limitations attend this type of control. The most substantial are the canard
25 drag forces and the consequential limited control authority afforded during the boost phase of the missile. The drag added by the rigidly extended canards impacts the overall missile design, especially for those missiles required to carry large propellant loads because of the range to be covered. The currently-used

extended-canard configuration severely reduces the missile range as well as speed. In cases of hypervelocity missiles, such as Compact Kinetic Energy Missile (C-KEM), the canard drag may nullify altogether the very advantage of maneuverability sought by using the canards.

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SUMMARY OF THE INVENTION

The Dragless Flight Control System for Flying Objects, referred to as the DFCS, greatly minimizes drag and, as a result, reduces the total power loss suffered by the object during its flight. With the DFCS, drag exists only when
10 the fins are proportionally extended for control purposes. When the object is set on its flying course, the fins are retracted completely into the body of the object, thus offering no resistance. Thus, the drag force exerted during the typical period that the fins are extended for control purposes is a mere fraction of the maximal drag force exerted by the permanently extended fins.

15 In DFCS, the retractable fins are mounted in pairs and are set to maximum no-stall angle 12 relative to axis 11 of flying object 100, the maximum angle being dependent on the operational speeds and the desired control characteristics of the particular object. The maximum angle is chosen to provide maximum lift over the range of the object's speeds while avoiding the
20 loss of lift due to the stalling of the fin. The fins are selectively exposable outside exterior skin 8 of the flying object by being rotated on their axes, the two fins of a pair always being rotated by the same rotation angle but in opposite directions. The degree of fin exposure is determined by the degree of rotation angle, the rotation angle being changeable to vary the portion of the fin being
25 exposed. Varying the exposed area of the counter-rotating fins can generate lift effect that is proportional to the exposed area and similar to that produced by the current extended standard rotational fins. When no lift force is needed, the fins

retract into a position flush with the exterior skin of the flying object, thus offering no drag.

DESCRIPTION OF THE DRAWING

5 Figure 1, views A and B present cross-sectional views of a representative pair of fins, with one fin fully-extended and with both fins retracted beneath exterior skin 8, respectively.

 Figure 2 depicts a preferred embodiment of the Dragless Flight Control System as it is positioned inside a flying object.

10 Figure 3 depicts an alternate embodiment of the Dragless Flight Control System.

 Figure 4 shows yet a third embodiment of the Dragless Flight Control System.

 Figure 5 shows the deployment of several pairs of fins on one flying
15 object to control roll and yaw.

 Figure 6 illustrates an effective packaging of multiple pairs of fins by deploying the pairs in non-linear fashion around the circumference of the flying object.

20 DESCRIPTION OF THE PREFERRED EMBODIMENT

 Referring now to the drawing wherein like numbers represent like parts in each of the several figures, the structure and operation of the DFCS is explained.

 A typical flying object in which the DFCS may be employed is missile
100 having body axis 11 that is parallel with the length of the missile and a
25 guidance computer (which may or may not be integral with controller 15) that, as a part of its guidance function, issues command signals for the desired rotational positions of fins 1 and 2. The two fins of a pair are mounted to rest in their respective housings 3 and 16 that are positioned to be on the same side of

missile body axis 11. The housings are mirrored on that side with axis 11 between them and are recessed into the body of the missile. Each of the fins has front end 18 and back end 17. In the preferred embodiment of DFCS as depicted in Figure 2, the front ends of the fins are closer together than the back ends of the fins. When no lift effect is desired for the missile, the fins are completely retracted into their respective housings, thereby exposing no part outside missile skin 8. When flush with the surface of the missile skin as illustrated in View B of Figure 1, no fin drag interferes with the aerodynamic properties of the missile's exterior configuration. When lift is desired, the fins are selectively exposed through the housing opening such that the movement vector of the fins is normal to the plane of the paper in Figure 2.

When lift control for the missile flight is desired, an electrical command signal indicating the desired fin position is sent from the computer to electronic controller 15. The electronic controller also receives information relative to the current fin rotational position. The current fin rotational position may be determined by any suitable means, such as by using hall sensors located in drive motor 5. The hall sensors derive the current fin rotational position information by counting the hall pulses generated by drive motor 5. While other methods of deriving the current fin rotational position information exist, the hall pulse counting method has the advantage of being able to accommodate the space and weight constraints of a missile. It is noted, however, that the hall pulse counting method necessitates an initialization of the fins at the "zero" position to which all other determined positions are held relative. The zero position of the fins is illustrated in View B of Figure 1. This is the stowed null-effect control position. To achieve the optimal operational efficiency of the DFCS during a flight and give the desired level of missile guidance lift force, fins 1 and 2 are variably positioned between the extreme positions illustrated in Figure 1, Views A and B.

Electronic controller 15 which is coupled via wire connector 10 to drive motor 5 receives the current fin rotational position information from the drive

motor and compares the information with the desired fin position command signal received from the guidance computer. From the comparison, an error signal is generated that is representative of a corrective angle and a voltage command corresponding to the corrective angle. This voltage is translated into rotation of the motor whose torque is delivered to transmission shaft 14 and, therefrom, simultaneously in opposite directions to both first fin gear shaft 13 and second fin gear shaft 19. The result is the rotation of fins 1 and 2 in opposite directions until the error signal is eliminated. The simultaneous transmission of the torque is accomplished by motor drive gear 7 which is coupled to first fin gear 6 and second fin gear 20. The first fin gear and second fin gear are, in turn, coupled to the first and second fin gear shafts, respectively. Because of the fins' alignment to the same motor drive gear 7, the rotation of the motor drive gear results in the rotation of the fins in mutually opposite directions. Motor transmission 4 "gears down" the rotational speed of the drive motor and multiplies the torque thereof prior to transmitting the torque to transmission shaft 14 that rotates motor drive gear 7. The motor transmission can take one of several gearing formats. Two that offer advantages of large gear ratios and small back lashes are a harmonic drive and a planetary drive.

The rotational movements of drive motor 5 from the neutral position in response to the error signals provides increasing control authority in proportion to the degree of rotational command given to the motor and in accordance with the rotational direction of the command. A clockwise error signal results in a voltage command that energizes the driving system (comprised of drive motor 5, motor transmission 4, first and second fin gears 6 and 20, first and second fin gear shafts 13 and 20, motor drive gear 7 and transmission shaft 14) to cause first fin 1 to be exposed outside missile skin 8 by rotating the fin by a pre-determined corrective angle while fin 2 is retracted into its corresponding housing by rotating it by the same pre-determined corrective angle. A counter-clockwise error signal results in a voltage command that reverses the rotational

motions of the fins. With either error signals, the rotation of the fins continues until the error signal is reduced to zero. In all cases, the fins do not rotate beyond a pre-set maximum angle.

Figure 3 shows an alternate embodiment of the Dragless Flight Control System in which front ends 18 of the fins are further apart from each other than back ends 17 of the fins. Figure 4 depicts yet another embodiment, that of fins in staggered positions. This positioning requires a separate motor drive gear for each fin. These alternate embodiments are equally effective in providing the desired actuation and the ultimate control of the fins and may differ only in their capability to meet a given space limitation in the flying object in which the DFCS is to be deployed.

The best effect of DFCS is achieved by using several pairs of the fins on one flying object, the pairs deployed at regular intervals from each other around the circumference of the object. Such a deployment is illustrated in a cross-sectional view of the object in Figure 5. Matched fin pairs with fins actuated in parallel angles allow yaw maneuvers while matched pairs with fins actuated in non-parallel angles allow roll maneuvers. Further, combinations of different embodiments can be employed as shown in Figure 6 for even more versatility.

Although particular embodiments and form of this invention have been illustrated, it is apparent that various modifications and other embodiments of the invention may be made by those skilled in the art without departing from the scope and spirit of the foregoing disclosure. For example, O-ring seals 9 can be used to seal fin gear shafts 13 and 19 rotationally with their respective housings 3 and 16. This permits avoidance of the external pressures that exist during the flight of the object. Further, the housings themselves may be sealed to skin 8 to prevent the external pressures from freely entering the flying object's body. Additionally, a pneumatic system, instead of direct electrical manipulation of the fins with electric motors as described above, may be used to introduce the fin pair into the air flow around the flying object. With the pneumatic system, the

fin pair is introduced proportionally into the air flow in a piston-like arrangement that allows the fins to slide in a linear fashion into position rather than rotate into position. Control solenoids regulate the pressure and flow to the fin pistons that alternately position the fin pair at the desired height in the air flow. Some of the advantages of such a pneumatic arrangement are greater actuation forces and alternate uses for the pneumatic exhaust, such as driving corresponding thrusters for flight assistance during the transition from launch where fins have little control authority. On the other hand, disadvantages of the pneumatic system include reduced packaging efficiency and increased system complexity due to integration requirements attendant to electrical/mechanical systems. In accordance with the foregoing, the scope of the invention should be limited only by the claims appended hereto.